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A BIBLIOMETRIC ANALYSIS OF BUILDING INFORMATION MODELING (BIM) INTEGRATION IN INDUSTRIALIZED BUILDING SYSTEMS (IBS): TRENDS, GAPS, AND FUTURE DIRECTIONS

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Abstract:

This bibliometric analysis investigates the integration of Building Information Modelling (BIM) within Industrialised Building Systems (IBS), focusing on research trends, knowledge gaps, and potential future directions. As construction and engineering fields increasingly adopt BIM for its efficiency and sustainability benefits, understanding its application in IBS becomes essential for advancing digital construction. Despite significant research on BIM and IBS separately, there is a limited comprehensive analysis of their combined application. This study addresses this gap by analyzing 1,559 relevant publications retrieved from the Scopus database, using Scopus Analyzer and VOSviewer software to examine co-authorship patterns, keyword co-occurrences, and citation networks. The findings reveal a substantial increase in research output on BIM-IBS integration over the past decade, particularly post-2018, with contributions from various countries, led by the United States, China, and the United Kingdom. Popular research themes include BIM's role in project management, sustainability, and emerging technologies like augmented reality and machine learning, highlighting a shift towards advanced, digitalized construction practices. Additionally, keyword analysis emphasizes the growing interest in interoperability and the integration of IoT within BIM-IBS frameworks. The results point to a well-developed but evolving field, with key areas for future research focused on improving data exchange, enhancing system interoperability, and expanding AI-driven applications in IBS. This study provides a comprehensive overview of the

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current research landscape, supporting researchers and industry practitioners in identifying collaboration opportunities and setting priorities for further innovation in BIM-integrated IBS practices.

Keywords:

Building Information Modeling (BIM), Industrial Building System (IBS), Construction, BIM Integration, Construction Industry

Introduction

Building Information Modeling (BIM) has emerged as a transformative technology in the architecture, engineering, and construction (AEC) industry, offering digital representations of facilities' physical and functional characteristics. Its integration with Industrialised Building Systems (IBS) presents a promising avenue for enhancing efficiency, reducing costs, and improving project outcomes. However, the adoption of BIM in IBS projects is fraught with challenges and opportunities that need to be systematically explored.

BIM facilitates the creation of detailed digital models that can be used throughout the planning, design, construction, and operational stages of a project. This technology promises significant benefits for IBS projects, including improved design visualization, better cost estimation, and enhanced project monitoring and control (Ibrahim *et al.,* 2022). Despite these advantages, the implementation of BIM in IBS is still in its nascent stages, particularly in regions like Malaysia, where the construction industry has been slow to adopt these innovations (Ern *et al.,* 2022).

One of the primary challenges in integrating BIM with IBS is the high cost associated with BIM tools, training, and expertise. This financial barrier limits its adoption primarily to large organizations that can afford the investment (Ibrahim *et al.,* 2022) (Ern *et al.,* 2022). Additionally, there are concerns about the complexity of BIM software, which can be difficult for stakeholders to understand and use effectively (Ibrahim *et al.,* 2022). Legal and intellectual property issues further complicate the widespread adoption of BIM in IBS projects (Ern *et al.,* 2022).

Despite these challenges, the potential benefits of BIM for IBS are substantial. BIM can address fragmentation issues in traditional construction processes, improving quality and productivity in IBS projects (Taib, 2019). Moreover, the integration of BIM with other technologies, such as the Internet of Things (IoT) and Geographic Information Systems (GIS), can further enhance the efficiency and sustainability of construction projects (Yin *et al.,* 2019).

Several measures can be taken to overcome the barriers to BIM adoption in IBS. Government initiatives to raise awareness, provide training, and offer incentives can play a crucial role in encouraging the adoption of BIM (Kang *et al.,* 2022). Additionally, developing standardized protocols for BIM integration and addressing interoperability issues can facilitate smoother implementation (Wang *et al.,* 2019).

In conclusion, while integrating BIM in IBS presents significant challenges, its potential benefits make it worthwhile. By addressing the financial, technical, and legal barriers and

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leveraging government support and technological advancements, the construction industry can harness the full potential of BIM to revolutionize IBS projects.

Literature Review

The integration of Building Information Modeling (BIM) with Industrialised Building Systems (IBS) in the construction industry has gained significant attention due to its potential to address the challenges of traditional construction methods, such as inefficiency, waste, and fragmentation. In the context of Malaysia, both BIM and IBS have emerged as key innovations aimed at improving construction efficiency and sustainability (Abkar *et al.,* 2024) (Haron *et al.,* 2015). Researchers have emphasized the role of these technologies in enhancing collaboration and streamlining processes within the Malaysian construction sector (Hashim *et al.,* 2024). BIM facilitates a collaborative environment by integrating design and construction information in a digital format, which, when combined with the prefabricated nature of IBS, can improve project timelines, reduce material wastage, and enhance overall quality (Haron *et al.,* 2015) (Razak *et al.,* 2022). Furthermore, there are studies (Nawi *et al.,* 2014) (Masyhur *et al.,* 2024) suggest that while the adoption of these technologies is progressing, the integration process faces substantial challenges, including resistance to change and lack of standardised protocols, which have hindered their widespread implementation.

A key trend identified in the literature is the increasing recognition of the potential of BIM-IBS integration to promote sustainable construction practices. As highlighted by some researchers (Z.-A. B. Ismail, 2020) (Z. A. Ismail *et al.,* 2020), the Malaysian construction sector is witnessing a shift towards more sustainable building practices, with a growing interest in green construction methods. BIM supports these initiatives by enabling better design accuracy, reducing energy consumption, and promoting more efficient resource use (Saar *et al.,* 2019). However, challenges remain, including the high initial costs of technology adoption, lack of skilled professionals, and limited knowledge on effectively combining BIM with IBS for green building design. These barriers are particularly evident in the context of IBS, where prefabricated components are often perceived as rigid and limited in design flexibility, further complicating their integration with BIM systems (Gunasagaran *et al.,* 2022). Despite these challenges, the need for sustainable solutions in construction, especially in light of Malaysia's environmental policies, continues to drive interest in BIM-IBS research (Razak *et al.,* 2022) (Masyhur *et al.,* 2024).

Another important theme in the literature is the ongoing exploration of the barriers and enablers for successfully integrating BIM and IBS. Meanwhile, the benefits of BIM-IBS integration are well documented, but practical challenges persist, particularly in terms of coordination between different stakeholders in the construction process. (Ang Soon Ern *et al.,* 2022) (Len *et al.,* 2021). The fragmented nature of the Malaysian construction industry, characterized by poor communication and coordination, exacerbates these difficulties (Jamalluddin *et al.,* 2022). To address these issues, the literature calls for a more integrated approach, such as using Integrated Project Delivery (IPD), which combines BIM and IBS to improve communication, reduce reworks, and minimize delays (Fawaz *et al.,* 2021). However, the slow adoption of IPD, especially in the context of traditional procurement methods, remains a significant barrier to effective BIM-IBS integration in Malaysia (Hashim *et al.,* 2024).

Further investigation into the gaps in the literature reveals that while many studies focus on the benefits of BIM and IBS, there is a limited exploration of how these technologies can be

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combined to address the specific needs of maintenance and defect management in IBS buildings. The integration of BIM with Computerized Maintenance Management Systems (CMMS) could significantly improve defect diagnosis and decision-making processes in the maintenance of IBS buildings (Razak *et al.,* 2022). However, there remains a lack of comprehensive frameworks and case studies on implementing such systems. This gap represents a significant opportunity for future research, as better maintenance management systems could enhance the long-term performance of IBS buildings, reducing costs and improving their sustainability (Charef *et al.,* 2019).

In conclusion, integrating BIM with IBS represents a promising avenue for innovation in the Malaysian construction industry. However, significant challenges remain, including resistance to technological adoption, lack of standardized protocols, and limited skilled labour. The current body of research has made important contributions to understanding these barriers and highlighting the potential benefits of BIM-IBS integration, particularly regarding sustainability and construction efficiency. Moving forward, there is a clear need for more research on the practical implementation of BIM and IBS in different stages of the construction lifecycle, including design, construction, and maintenance. Studies exploring the integration of BIM with maintenance management systems, as well as the development of comprehensive frameworks for BIM-IBS collaboration, will be crucial in advancing this field.

Research Question

a. What are the research trends in online learning studies according to the year of publication?
b. Who and how much has been published in the area concerning the authors?
c. Who are the top 10 authors based on citation by research?
d. What are the popular keywords related to the study?
e. What are co-authorship countries' collaboration?

Methodology

Bibliometrics refers to the collection, management, and analysis of bibliographic data derived from scientific publication's descriptive statistics, such as publishing journals, publication years, and classification of primary authors, as well as advanced method sent co-citation analysis (Alves *et al.,* 2021; Assyakur & Rosa, 2022; Verbeek *et al.,* 2002). Conducting a comprehensive literature review requires an iterative approach, including identifying suitable keywords, searching relevant literature, and performing a detailed analysis to create a thorough bibliography and obtain reliable findings (Wu & Wu, 2017). In line with this, the study concentre-impact publications, as they provide key insights into the theoretical frameworks shaping the field's progression (Fahimnia *et al.,* 2015). To ensure data accuracy, the SCOPUS database was selected as the primary source for data collection (Al-Khoury *et al.,* 2022; di Stefano *et al.,* 2010; Khiste & Paithankar, 2017). Furthermore, peer-reviewed academic journals were included to maintain a focus on quality, while books and lecture notes were intentionally excluded. Elsevier's Scopus, known for its extensive reach, enabled the compilation of s from 2020 to December 2023 for analysis.

Data Search Strategy

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Advanced searching on the Scopus database is a feature that allows users to perform highly specific and targeted searches to retrieve relevant academic publications. Unlike basic searches, which may simply involve typing keywords, advanced searching enables users to combine multiple criteria, use Boolean operators (such as AND, OR, and NOT), and apply various filters to refine their results. This helps researchers find precisely the information they need by narrowing down the vast database content to match particular topics, authors, time periods, document types, or other relevant aspects. Tables 1 and 2 show the keyword searching and inclusion and exclusion criteria.

Table 1: The Search String.

Scopus	TITLE-ABS-KEY ("building information modelling" AND construction) AND PUBYEAR > 2009 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (EXACT KEYWORD, "Building Information Modeling")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p")).

Table 2: The Selection Criterion Is Searching.

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2010–2024	< 2020
Literature type	Journal (Article) and Proceeding	Book, Review

Data Analysis

VOSviewer is a user-friendly bibliometric tool developed by Nees Jan van Eck and Ludo Waltman at Leiden University in the Netherlands (van Eck & Waltman, 2010, 2017). It is widely used for visualizing and analyzing scientific literature, particularly for creating intuitive network visualizations, clustering similar items, and generating density maps. VOSviewer allows researchers to explore co-authorship, co-citation, and keyword co-occurrence networks, offering a comprehensive view of research landscapes. Its interactive interface, combined with frequent updates, supports the efficient exploration of large datasets. With capabilities for computing metrics, customizing visualizations, and integrating with various bibliometric data sources, VOSviewer is a valuable resource for scholars aiming to gain insights into complex research fields.

A key feature of VOSviewer is its ability to convert complex bibliometric data into easily interpretable visual maps and charts. Emphasizing network visualization, the software is highly effective in clustering related items, analyzing keyword co-occurrence patterns, and producing density maps. Its user-friendly interface caters to both beginners and experienced users, allowing for effective exploration of research landscapes. With continuous development,

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VOSviewer remains a leading tool in bibliometric analysis, offering valuable metrics, customizable visuals, and flexibility in handling different types of data, such as co-authorship and citation networks, making it an indispensable tool for scholars seeking deep insights into their research domains.

Datasets containing information on publication year, title, author name, journal, citations, and keywords in PlainText format were gathered from the Scopus database, covering the period from 2010 to December 2024. These datasets were analyzed using VOSviewer version 1.6.19. Through VOS clustering and mapping techniques, VOSviewer facilitated the creation of maps. Unlike the Multidimensional Scaling (MDS) approach, VOSviewer places items in low-dimensional spaces, ensuring that the distance between items accurately reflects their relatedness and similarity (Appio *et al.*, 2014). Meanwhile, VOSviewer shares similarities with MDS, such as focusing on proximity-based relationships, it differs by employing a more suitable normalization method for co-occurrence frequencies, including association strength (ASij), which is calculated as (Van Eck & Waltman, 2007):

$$AS_{ij} = \frac{C_{ij}}{W_i W_j},$$

which is "proportional to the ratio between on the one hand the observed number of co-occurrences of i and j and on the other hand the expected number of co-occurrences of i and j under the assumption that co-occurrences of i and j are statistically independent" [32].

Result and Discussion

RQ1: What Are The Research Trends In Online Learning Studies According To The Year Of Publication?

Figure 1 illustrates the publication trend of documents related to integrating Building Information Modelling (BIM) in Industrialised Building Systems (IBS) from 2010 to 2024, based on Scopus data. The overall trend shows a significant increase in publication output, particularly from 2018 onwards. Between 2010 and 2017, the annual number of documents remained relatively stable, averaging around 50 publications annually. However, starting in 2018, the data shows a sharp upward trajectory in publications, reflecting a growing interest in this research area. This surge may be attributed to the increasing global recognition of BIM's potential to improve productivity, sustainability, and efficiency within industrialized construction practices.

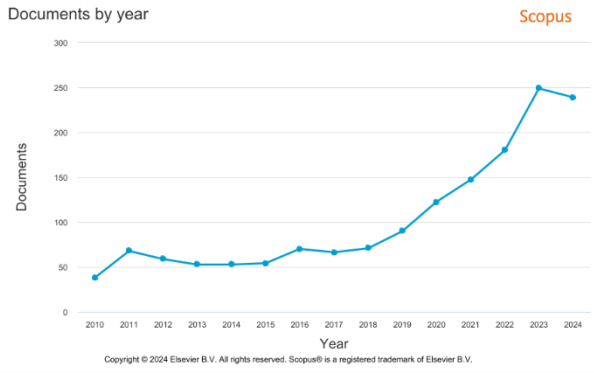

Figure 1: Plotting Document Publication By Years.

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The peak in publications occurred in 2023, with over 250 documents indicating that BIM-IBS integration has become a popular research topic. Meanwhile, there is a slight decline in 2024, and the overall trend suggests sustained interest and ongoing research. This recent increase could indicate that technological advancements, government policies, and industry demands have driven more research into integrating BIM with IBS practices. The steady rise in publication output highlights the importance of exploring new frameworks, methods, and technologies to improve the adoption and effectiveness of BIM in industrialized building systems.

RQ2: Who And How Much Has Been Published In The Area Concerning The Authors?

Figure 2 displays the trend in the number of documents published by authors on the topic of BIM integration in Industrialized Building Systems (IBS) from 2010 to 2024. Initially, from 2010 to around 2017, the publication volume remained relatively low and stable, with minor fluctuations averaging around 50 to 60 documents per year. This suggests that research interest in BIM-IBS integration was limited during this period, possibly due to the novelty of the concept or limited awareness and adoption of BIM in industrialized construction. Researchers may have focused on foundational studies exploring the potential benefits and challenges of applying BIM to IBS without widespread implementation.

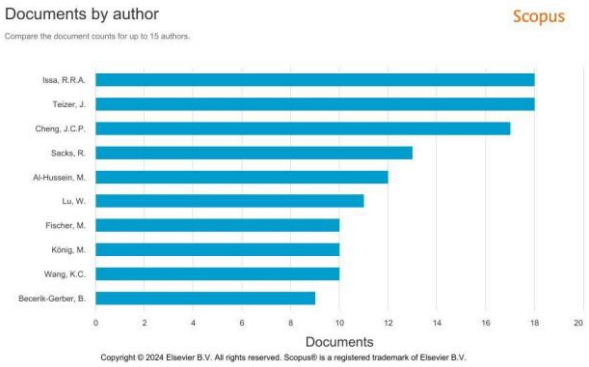

Figure 2: Top 10 Authors by Document Count on BIM Integration in Industrialized Building Systems (2004–2024).

Table 3: Top 10 Authors Based On Citation By Research.

Author Name	Number of Document	Percentage (%)
Issa, R.R.A.	18	1.155
Teizer, J.	18	1.155
Cheng, J.C.P.	17	1.090
Sacks, R.	13	0.834
Al-Hussein, M.	12	0.770
Lu, W.	11	0.706
Fischer, M.	10	0.641
König, M.	10	0.641
Wang, K.C.	10	0.641
Becerik-Gerber, B.	9	0.577

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A notable increase in publications begins around 2018, with a sharp upward trajectory continuing through 2023, peaking at over 250 documents. This growth reflects an accelerated interest in BIM-IBS integration, driven likely by technological advancements, increased industry adoption, and supportive policies from governments advocating for digital transformation in construction. The slight decline in 2024 may indicate a temporary stabilization or shift in focus within this research area. Overall, the trend highlights a maturing research field with rising interest, pointing to new opportunities for addressing research gaps and exploring advanced applications of BIM in industrialized building systems.

RQ3: Who Are The Top 10 Authors Based On Citation By Research?

Table 4 showcases the top 10 most-cited authors from 2010 to 2024 on the topic of BIM integration in Industrialised Building Systems (IBS), revealing significant contributions to the field through various impactful studies. Leading this group is the 2010 publication by Sacks, Koskela, Dave, and Owen, which explores the interaction of lean construction principles with BIM, garnering 493 citations. Their work has been foundational in understanding how lean methodologies can be integrated with BIM to enhance construction efficiency and productivity, highlighting its high relevance and broad influence in the field.

Table 4: Top 10 Most-Cited Authors on BIM Integration in Industrialized Building Systems (2010–2024).

Authors	Title	Year	Journal	Cited by
Sacks R. *et al.*	Interaction of lean and building information modeling in construction	2010	Journal of Construction Engineering and Management	493
Porwal A.; Hewage K.N. (Porwal & Hewage, 2013)	Building Information Modeling (BIM) partnering framework for public construction projects	2013	Automation in Construction	369
Barlish K.; Sullivan K. (Barlish & Sullivan, 2012)	How to measure the benefits of BIM - A case study approach	2012	Automation in Construction	517
Zhang S. *et al.* (Zhang *et al.*, 2015)	BIM-based fall hazard identification and prevention in construction safety planning	2015	Safety Science	356
Miettinen R.; Paavola S. (Miettinen & Paavola, 2014)	Beyond the BIM utopia: Approaches to the development and implementation of building information modeling	2014	Automation in Construction	355
Azhar S. (Azhar, 2011)	Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry	2011	Leadership and Management in Engineering	1504

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Peng C. (Peng, 2016)	Calculation of a building's life cycle carbon emissions based on Ecotect and building information modeling	2016	Journal of Cleaner Production	322
Becerik-Gerber B.; *et al.* (Becerik-Gerber *et al.*, 2012)	Application areas and data requirements for BIM-enabled facilities management	2012	Journal of Construction Engineering and Management	716
Azhar S. *et al.* (Azhar *et al.*, 2011)	Building information modeling for sustainable design and LEED ® rating analysis	2011	Automation in Construction	464
Sacks R. *et al.* (Sacks *et al.*, 2020)	Construction with digital twin information systems	2020	Data-Centric Engineering	336

Another prominent study is the 2012 publication by Barlish and Sullivan, which ranks even higher in citations with 517. This study focuses on measuring the benefits of BIM through case studies, providing an empirical approach to assess BIM's value in the industrialized construction sector. The high citation count indicates that quantifying BIM's tangible benefits has been a priority for academia and industry, reinforcing the importance of data-driven evaluations in validating BIM's role within IBS. Meanwhile, Porwal and Hewage's 2013 research on BIM partnering frameworks, which has received 369 citations, emphasizes the importance of collaborative frameworks for BIM implementation in construction, underlining the sector's need for effective partnerships and coordination.

Other notable works include the 2015 study by Zhang, Sulankivi, Kiviniemi, and Romo, which explores BIM's application in fall hazard prevention, reflecting an interest in safety applications within industrialized building environments. Their work, along with Miettinen and Paavola's 2014 study on BIM development approaches (355 citations), demonstrates the expanding scope of BIM research beyond process efficiency and cost savings to address critical areas like safety and development frameworks. Collectively, these highly cited studies underscore a wide array of research interests—from lean integration and benefit measurement to safety and partnership frameworks—showcasing the evolving priorities in BIM-IBS research and identifying foundational contributions and emerging trends in the field.

RQ4: What Are The Popular Keywords Related To The Study?

Figure 3 shows an analysis of BIM integration in Industrialized Building Systems (IBS) and significant trends in research areas, as visualized in VOS Viewer. The high occurrences of keywords like "building information modeling" (1098 occurrences, 1526 total link strength) and "BIM" (129 occurrences, 278 total link strength) emphasize BIM's central role in the construction and related technologies. The prominence of terms like "construction industry" (44 occurrences, 90 total link strength) and "project management" (30 occurrences, 65 total link strength) highlights BIM's integration into construction workflows and management practices, signifying its importance for efficiency, cost control, and coordination across complex projects.

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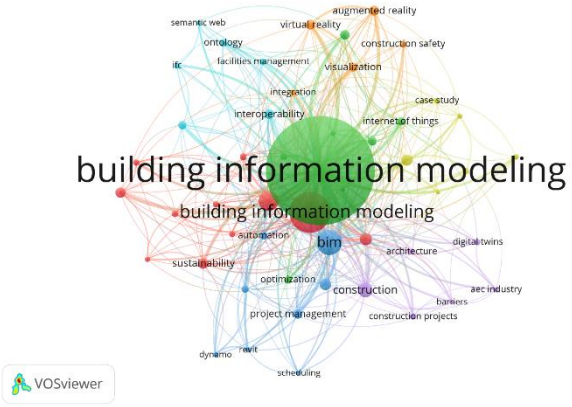

Figure 3: Network Visualization Map Of Keywords Co-Occurrence.

Emerging technologies like "augmented reality" (33 occurrences, 75 total link strength), "virtual reality" (32 occurrences, 76 total link strength), and "machine learning" (19 occurrences, 44 total link strength) reflect advancements in BIM visualization and data analysis capabilities. These technologies offer transformative potential for enhancing real-time decision-making, project visualization, and immersive training within the construction industry. Furthermore, topics such as "sustainability" (38 occurrences, 87 total link strength) and "life cycle assessment" (35 occurrences, 75 total link strength) indicate a growing focus on environmental impact, aligning with industry priorities for sustainable development.

Lastly, the clustering of keywords related to interoperability, such as "Internet of Things (IoT)" (25 occurrences, 60 total link strength) and "interoperability" (32 occurrences, 69 total link strength), highlights the demand for integrated, connected construction systems. This integration supports smoother data exchange between BIM platforms and other systems, such as "industry foundation classes (IFC)" (20 occurrences, 43 total link strength). Overall, while BIM is already deeply embedded in project management and sustainability, future research directions should focus on strengthening interoperability and leveraging AI-driven insights to optimize IBS projects further.

RQ5: What Are The Collaborations Of Co-Authorship Countries'?

The co-authorship analysis from Figure 4 reveals the global landscape of collaborative research on BIM integration in IBS, with notable contributions from countries across multiple continents. The United States leads in document count (331) and citations (12,182), reflecting its significant influence and extensive research output in this field. China follows with 262 documents and 5,051 citations, showing strong research activity and a high level of collaboration with a total link strength of 128, indicating extensive international partnerships. Other top contributors include the United Kingdom (105 documents, 3,564 citations) and Germany (101 documents, 2,453 citations), highlighting Europe's substantial role in advancing BIM research.

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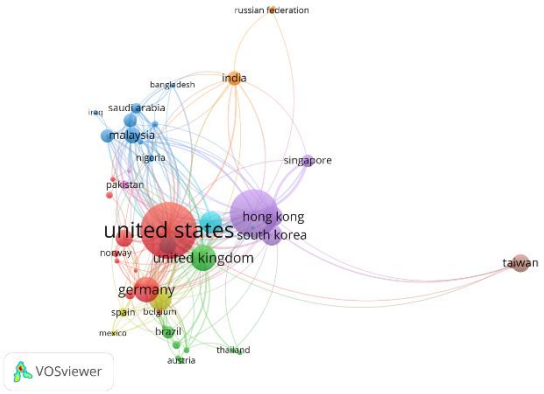

Figure 4: The Global Landscape Of Collaborative Research On BIM Integration In IBS.

Several Asian countries are also highly active in BIM-IBS research. Hong Kong, for instance, has 74 documents and a notable 3,717 citations, with a total link strength of 70, suggesting robust connections with other researchers worldwide. South Korea (78 documents, 2,827 citations) and Taiwan (62 documents, 1,027 citations) also show considerable research engagement, underscoring the importance of BIM in Asia's construction industry. Malaysia stands out with 54 documents and a relatively high total link strength of 58, indicating Malaysia's emerging position in this research area and its collaborative ties with other countries, potentially due to its emphasis on industrialized building methods and government support for digital construction technologies.

Some countries, though producing fewer documents, have substantial citation counts, which signifies the impactful nature of their research. For example, Finland has only 24 documents but has garnered 1,457 citations, showing the high-quality and influence of its contributions. This trend suggests that while the United States and China dominate in volume, smaller countries can still significantly impact, especially through high-quality publications and focused international collaborations. Future research could benefit from increased collaborations among less-represented regions to broaden the scope and application of BIM in IBS globally.

Conclusion

In conclusion, the bibliometric analysis reveals a clear upward trend in research output on BIM integration in IBS, with a marked increase beginning in 2018. This growth aligns with the global rise in interest in digital transformation within construction, supported by advancements in BIM technology, industry demands for greater productivity, and government initiatives encouraging digitalization. The peak publication activity in 2023 reflects the recognition of BIM's potential to enhance the efficiency and sustainability of industrialized construction practices. Although a slight dip is observed in 2024, the upward trajectory indicates sustained interest and ongoing development in this field.

The analysis of author contributions and citation data highlights the influence of specific foundational studies, particularly those focusing on lean construction integration, empirical benefits assessment, and collaborative frameworks. These studies have shaped the direction of BIM-IBS research by providing critical insights into the practical applications and advantages of BIM within industrialized systems. Notably, recent publications also explore areas such as

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safety and partnership frameworks, suggesting an expanding scope in BIM research that addresses not only operational efficiency but also broader issues in construction management and collaboration. This evolution of research priorities underscores the continued relevance and potential for further innovation in integrating BIM within IBS.

The analysis highlights a global collaborative network in research on BIM integration within Industrialized Building Systems (IBS), with major contributions from countries across continents. Leading this field, the United States shows the highest output with 331 documents and 12,182 citations, indicating both extensive research and global influence. China follows with substantial output and a high total link strength, reflecting active international collaboration. The United Kingdom and Germany also emerge as key contributors, positioning Europe as a major player in advancing BIM research. Asian countries, notably Hong Kong, South Korea, and Taiwan, demonstrate significant engagement, indicating BIM's growing role in the construction industry across Asia. Malaysia's notable collaboration strength reflects its emphasis on digital construction technologies and industrialized building methods.

Meanwhile, countries like the United States and China dominate in research volume, while others, such as Finland, achieve substantial impact through high citation counts despite fewer publications. This suggests that high-quality, focused research can yield significant influence, especially when paired with strategic international collaborations. Overall, the collaboration patterns indicate that while larger countries lead in publication volume, smaller nations contribute high-impact research. Future advancements in BIM-IBS research could be enhanced by expanding partnerships with underrepresented regions, encouraging broader and more diverse perspectives on BIM integration in industrialized construction.

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References

Abkar, M. M. A., Yunus, R., Gamil, Y., & Albaom, M. A. (2024). Enhancing construction site performance through technology and management practices as material waste mitigation in the Malaysian construction industry. Heliyon, 10(7). https://doi.org/10.1016/j.heliyon.2024.e28721

Al-Khoury, A., Hussein, S. A., Abdulwhab, M., Aljuboori, Z. M., Haddad, H., Ali, M. A., Abed, I. A., & Flayyih, H. H. (2022). Intellectual Capital History and Trends: A Bibliometric Analysis Using Scopus Database. Sustainability (Switzerland), 14(18). https://doi.org/10.3390/su141811615

Alves, J. L., Borges, I. B., & De Nadae, J. (2021). Sustainability in complex projects of civil construction: Bibliometric and bibliographic review. Gestao e Producao, 28(4). https://doi.org/10.1590/1806-9649-2020v28e5389

Ang Soon Ern, P., Xian Yang, W., Kasim, N., Hairi Osman, M., Hani Adnan, S., Suhada Natasha, N., & Ali, R. (2022). Building Information Modelling (BIM) in Malaysian Industrialised Building System (IBS) Construction Projects: Benefits and Challenges. In R. S.N., R. N.A., T. N.A., K. M.H., J. J., T. Z.A., N. N.M., S. E.M., bin S. A., B. R., M. S. S.M., & Y. S.K. (Eds.), IOP Conference Series: Earth and Environmental Science

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 6 Issue 19 (December 2024) PP. 176-190
DOI 10.35631/IJIREV.619014

(Vol. 1022, Issue 1). Institute of Physics. https://doi.org/10.1088/1755-1315/1022/1/012020

Appio, F. P., Cesaroni, F., & Di Minin, A. (2014). Visualizing the structure and bridges of the intellectual property management and strategy literature: a document co-citation analysis. Scientometrics, 101(1), 623–661. https://doi.org/10.1007/s11192-014-1329-0

Assyakur, D. S., & Rosa, E. M. (2022). Spiritual Leadership in Healthcare: A Bibliometric Analysis. Jurnal Aisyah : Jurnal Ilmu Kesehatan, 7(2). https://doi.org/10.30604/jika.v7i2.914

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. Leadership and Management in Engineering, 11(3), 241–252. https://doi.org/10.1061/(ASCE)LM.1943-5630.0000127

Azhar, S., Carlton, W. A., Olsen, D., & Ahmad, I. (2011). Building information modeling for sustainable design and LEED ® rating analysis. Automation in Construction, 20(2), 217–224. https://doi.org/10.1016/j.autcon.2010.09.019

Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM - A case study approach. Automation in Construction, 24, 149–159. https://doi.org/10.1016/j.autcon.2012.02.008

Becerik-Gerber, B., Jazizadeh, F., Li, N., & Calis, G. (2012). Application areas and data requirements for BIM-enabled facilities management. Journal of Construction Engineering and Management, 138(3), 431–442. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000433

Charef, R., Emmitt, S., Alaka, H., & Fouchal, F. (2019). Building Information Modelling Adoption in the European Union: An overview. Journal of Building Engineering. https://doi.org/10.1016/J.JOBE.2019.100777

di Stefano, G., Peteraf, M., & Veronay, G. (2010). Dynamic capabilities deconstructed: A bibliographic investigation into the origins, development, and future directions of the research domain. Industrial and Corporate Change, 19(4), 1187–1204. https://doi.org/10.1093/icc/dtq027

Ern, P. A. S., Yang, W. X., Kasim, N., Osman, M. H., Adnan, S. H., Natasha, N. S., & Ali, R. (2022). Building Information Modelling (BIM) in Malaysian Industrialised Building System (IBS) Construction Projects: Benefits and Challenges. IOP Conference Series: Earth and Environmental Science, 1022. https://doi.org/10.1088/1755-1315/1022/1/012020

Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management: A review and bibliometric analysis. In International Journal of Production Economics (Vol. 162, pp. 101–114). https://doi.org/10.1016/j.ijpe.2015.01.003

Fawaz, M., Ibrahim, R., Rashidi, A., & Ghafar, M. A. (2021). FROM MODELLING TO MANAGEMENT OF PROJECT DELIVERY: REVIEW ON CLASH MANAGEMENT PROCESS WITH BIM IN MALAYSIA. Malaysian Construction Research Journal, 35(3).

Gunasagaran, S., Yung, L. K., Mohamed, M. R., & Mari, T. (2022). INTEGRATING SYSTEM THINKING IN INDUSTRIALISED BUILDING SYSTEM (IBS) IN MALAYSIA. Journal of Engineering Science and Technology, 17.

Haron, A. T., Marshall-Ponting, A. J., Zakaria, Z., Nawi, M. N. M., Hamid, Z. A., & Kamar, K. A. M. (2015). An industrial report on the Malaysian building information modelling (BIM) taskforce: Issues and recommendations. Malaysian Construction Research Journal, 17(1), 21–36. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84976254578&partnerID=40&md5=3d0b1f00ffb93c6d4e815e2d8355d207

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 6 Issue 19 (December 2024) PP. 176-190
DOI 10.35631/IJIREV.619014
Hashim, M. Z., Othman, I., Khalid, N. S. M., Hassan, S. H., & Musa, M. K. (2024). Construction Players' Awareness of the Use of Building Information Modelling (BIM) and Industrialized Building Systems (IBS) in the Malaysian Construction Industry. In M. B.S., M. T.H., S. M.H., J. T.B., & A. S. (Eds.), Lecture Notes in Civil Engineering (Vol. 324, pp. 491–504). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/978-981-99-1111-0_42

Ibrahim, I. H., Tuanku Karim, S. F., Ismail, N. A. A., & Syed Jamaludin, S. Z. H. (2022). Adopting Building Information Modelling (BIM) into Industrialised Building System (IBS) in the Malaysian Construction Industry. Journal of Smart Science and Technology, 2(2). https://doi.org/10.24191/jsst.v2i2.20

Ismail, Z.-A. B. (2020). Towards a BIM-based approach for improving maintenance performance in IBS building projects. Engineering, Construction, and Architectural Management, 28(5), 1468–1490. https://doi.org/10.1108/ECAM-07-2020-0508

Ismail, Z. A., Abdul Rahim, M., & Ghazaly, Z. M. (2020). BIM and CMMS for IBS building maintenance in Malaysia. IOP Conference Series: Earth and Environmental Science, 476(1). https://doi.org/10.1088/1755-1315/476/1/012012

Jamalluddin, N. A., Adnan, H., Bakhary, N. A., & Rosman, M. R. (2022). Risk Mitigation in Industrialized Building System (IBS) Construction. IOP Conference Series: Earth and Environmental Science, 1067(1). https://doi.org/10.1088/1755-1315/1067/1/012065

Kang, K.-Y., Wang, X., Wang, J., Xu, S., Shou, W., & Sun, Y. (2022). Utility of BIM-CFD Integration in the Design and Performance Analysis for Buildings and Infrastructures of Architecture, Engineering and Construction Industry. Buildings. https://doi.org/10.3390/buildings12050651

Khiste, G. P., & Paithankar, R. R. (2017). Analysis of Bibliometric term in Scopus. International Research Journal, 01(32), 78–83.

Len, T. K., Ern, P. A. S., & Lin, P. Y. (2021). Investigating Significant Issues of BIM Implementation in Industrialised Building System Design and Production Process. International Journal of Sustainable Construction Engineering and Technology, 12(3 Special issue). https://doi.org/10.30880/ijscet.2021.12.03.021

Masyhur, R. T., Alias, A. H., Haron, N. A., & Zulkafli, Z. (2024). A systematic review on green practices in the Malaysian construction industry: Status, challenges, key motivations, rating systems, and technology evolution. Energy and Buildings, 320. https://doi.org/10.1016/j.enbuild.2024.114550

Miettinen, R., & Paavola, S. (2014). Beyond the BIM utopia: Approaches to the development and implementation of building information modeling. Automation in Construction, 43, 84–91. https://doi.org/10.1016/j.autcon.2014.03.009

Nawi, M. N. M., Haron, A. T., Hamid, Z. A., Kamar, K. A. M., & Baharuddin, Y. (2014). Improving integrated practice through Building Information Modeling-Integrated Project Delivery (BIM-IPD) for Malaysian Industrialised Building System (IBS) construction projects. Malaysian Construction Research Journal, 15(2).

Peng, C. (2016). Calculation of a building's life cycle carbon emissions based on Ecotect and building information modeling. Journal of Cleaner Production, 112, 453–465. https://doi.org/10.1016/j.jclepro.2015.08.078

Porwal, A., & Hewage, K. N. (2013). Building Information Modeling (BIM) partnering framework for public construction projects. Automation in Construction, 31, 204–214. https://doi.org/10.1016/j.autcon.2012.12.004

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 6 Issue 19 (December 2024) PP. 176-190
DOI 10.35631/IJIREV.619014

Razak, M. I. A., Khoiry, M. A., Badaruzzaman, W. H. W., & Hussain, A. H. (2022). DfMA for a Better Industrialised Building System. In Buildings (Vol. 12, Issue 6). https://doi.org/10.3390/buildings12060794

Saar, C. C., Siang, T. C., Ahmad Bajuri, F. A., Chuing, L. S., Yusof, A. M., & Sheng, L. X. (2019). Building information modelling in Malaysian industrialized building system. In S. B.Y., S. null, H. null, & D. S. (Eds.), IOP Conference Series: Materials Science and Engineering (Vol. 620, Issue 1). Institute of Physics Publishing. https://doi.org/10.1088/1757-899X/620/1/012047

Sacks, R., Brilakis, I., Pikas, E., Xie, H. S., & Girolami, M. (2020). Construction with digital twin information systems. Data-Centric Engineering, 1(6). https://doi.org/10.1017/dce.2020.16

Taib, M. (2019). Improvising Industrialised Building System Through The Adoption Of Building Information Modeling. https://doi.org/10.15405/epms.2019.12.3

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

van Eck, N. J., & Waltman, L. (2017). Citation-based clustering of publications using CitNetExplorer and VOSviewer. Scientometrics, 111(2), 1053–1070. https://doi.org/10.1007/s11192-017-2300-7

Van Eck, N. J., & Waltman, L. (2007). Bibliometric mapping of the computational intelligence field. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 15(5), 625–645. https://doi.org/10.1142/S0218488507004911

Verbeek, A., Debackere, K., Luwel, M., & Zimmermann, E. (2002). Measuring progress and evolution in science and technology - I: The multiple uses of bibliometric indicators. International Journal of Management Reviews, 4(2), 179–211. https://doi.org/10.1111/1468-2370.00083

Wang, H., Pan, Y., & Luo, X. (2019). Integration of BIM and GIS in sustainable built environment: A review and bibliometric analysis. Automation in Construction. https://doi.org/10.1016/J.AUTCON.2019.03.005

Wu, Y. C. J., & Wu, T. (2017). A decade of entrepreneurship education in the Asia Pacific for future directions in theory and practice. In Management Decision (Vol. 55, Issue 7, pp. 1333–1350). https://doi.org/10.1108/MD-05-2017-0518

Yin, X., Liu, H., Chen, Y., & Al-Hussein, M. (2019). Building information modelling for off-site construction: Review and future directions. Automation in Construction. https://doi.org/10.1016/J.AUTCON.2019.01.010

Zhang, S., Sulankivi, K., Kiviniemi, M., Romo, I., Eastman, C. M., & Teizer, J. (2015). BIM-based fall hazard identification and prevention in construction safety planning. Safety Science, 72, 31–45. https://doi.org/10.1016/j.ssci.2014.08.001